CLAIMS:

1. A feature comparison apparatus comprising:

input means for receiving an input signal;

recognition processing means for comparing said input signal with stored feature models to identify an input sequence of features in said input signal and confidence data representative of the confidence that the input sequence of features is representative of said input signal; and

means for comparing said input sequence of features with a stored sequence of features using predetermined similarity data which defines similarities between different features and using said confidence data, to provide a measure of the similarity between the input sequence of features and the stored sequence of features.

2. An apparatus according to claim 1, wherein confidence data is stored for said stored sequence of features and wherein said comparing means provides said similarity measure using, in addition, said stored confidence data.

3. The apparatus according to claim 1, wherein said confidence data comprises confidence data associated with each feature in the sequence of features.

4. An apparatus according to claim 1, wherein said recognition processing means is operable to output a list of alternatives for each feature in said input sequence of features and confidence data associated with each alternative.

5. An apparatus according to claim 1, wherein said comparing means comprises:

means for aligning features of the input sequence of features with features of the stored sequence of features to form a number of aligned pairs of features;

means for comparing the features of each aligned pair of features using said predetermined similarity data and said confidence data, to generate a comparison score representative of the similarity between the aligned pair of features; and

means for combining the comparison scores for all the aligned pairs of features to provide said similarity measure.

6. An apparatus according to claim 5, wherein said comparing means comprises:

first comparing means for comparing, for each aligned pair, the input sequence feature in the aligned pair with each of a plurality of features taken from a set of predetermined features using said similarity data and said confidence data to provide a corresponding plurality of intermediate comparison scores representative of the similarity between said first sequence feature and the respective features from the set;

second comparing means for comparing, for each aligned pair, the stored sequence feature in the aligned pair with each of said plurality of features from the set using said similarity data and said confidence data to provide a further corresponding plurality of intermediate comparison scores representative of the similarity between said stored sequence feature and the respective features from the set; and

means for calculating said comparison score for the aligned pair by combining said pluralities of intermediate comparison scores.

7. An apparatus according to claim 6, wherein said first and second comparing means are operable to compare the input sequence feature and the stored sequence feature respectively with each of the features in said set of predetermined features.

8. An apparatus according to claim 6, wherein said comparing means is operable to generate a comparison score for an aligned pair of features which represents a probability of confusing the stored sequence feature of the aligned pair as the input sequence feature of the aligned pair.

9. An apparatus according to claim 8, wherein said first and second comparing means are operable to provide intermediate comparison scores which are indicative of a probability of confusing the corresponding feature taken from the set of predetermined features as the feature in the aligned pair.

10. An apparatus according to claim 9, wherein said calculating means is operable (i) to multiply the intermediate scores obtained when comparing the input and stored sequence features in the aligned pair with the same feature from the set to provide a plurality of multiplied intermediate comparison scores; and (ii) to add the resulting multiplied intermediate scores, to calculate said comparison score for the aligned pair.

11. An apparatus according to claim 10, wherein each of said features in said set of predetermined features has a predetermined probability of occurring within a sequence of features and wherein said calculating means is operable to weigh each of said multiplied intermediate comparison scores with the respective probability of occurrence for the feature from the set used to generate the multiplied intermediate comparison scores.

12. An apparatus according to claim 11, wherein said calculating means is operable to calculate:

$$\sum_{r=1}^{n} P(q_j|p_r)P(a_i|p_r)P(p_r)$$

where q_j and a_i are an aligned pair of input and stored sequence features respectively; $P(q_j|p_r)$ is the probability of confusing set feature p_r as input sequence feature q_j; $P(a_i|p_r)$ is the probability of confusing set feature p_r as stored sequence feature a_i; and $P(p_r)$ represents the probability of set feature p_r occurring in a sequence of features.

13. An apparatus according to claim 12, wherein the confusion probabilities for the input and stored sequence features are determined in advance and depend upon the recognition system that was used to generate the respective input in stored sequences.

14. An apparatus according to claim 12, wherein said calculating means is operable to calculate $P(q_j|p_r)$ using said similarity data and said confidence data.

15. An apparatus according to claim 14, wherein said

calculating means is operable to take a weighted combination of said similarity data and said confidence data to determined $P(q_j|p_r)$.

16. An apparatus according to claim 15, wherein said similarity data is obtained from a training session in which a large amount of input signals for which the feature content is known are processed by said recognition processing means and wherein said calculating means is operable to weigh said confidence data for a current feature in dependence upon the amount of training data available for the current feature in said training session.

17. An apparatus according to claim 16, wherein said calculating means is operable to calculate:

$$P(q_j|p_r) = \frac{b_c c_{jr} + b_e e^r_{qj} + \beta}{b_c n_r + b_e + N_p \beta}$$

where c_{jr} and n_r are counts generated during the training session for the number of times the recognition processing means decoded feature q_j when it should have decoded feature p_r and the number of times the recognition processing means decoded anything when it should have decoded feature p_r, respectively; $e_{qj}{}^r$ is the confidence data associated with the input sequence feature of the aligned pair which is associated with the set feature P_r; β represents a lower limit of the confidence probabilities; N_p is the total number of features in the set; and b_c and b_e are scaling factors which are applied to the similarity data and the confidence data respectively.

18. An apparatus according to claims 10, wherein said intermediate scores represent log probabilities and wherein said calculating means is operable to perform said multiplication by adding the respective intermediate scores and is operable to perform said addition of said multiplied scores by performing a log addition calculation.

19. An apparatus according to claim 18, wherein said combining means is operable to add the comparison scores for all the aligned pairs to determine said similarity measure.

20. An apparatus according to claim 5, wherein said aligning means is operable to identify feature deletions and insertions in said input and stored sequences of features and wherein said comparing means is operable to generate said comparison score for an aligned pair of features in dependence upon feature deletions and insertions identified by said aligning means which occur in the vicinity of the features in the aligned pair.

21. An apparatus according to claim 5, wherein said aligning means comprises dynamic programming means for aligning said input and stored sequences of features using a dynamic programming technique.

22. An apparatus according to claim 21, wherein said dynamic programming means is operable to determine progressively a plurality of possible alignments between said input and stored sequences of features and wherein said comparing means is operable to determine a comparison score for each of the possible aligned pairs

of features determined by said dynamic programming means.

23. An apparatus according to claim 22, wherein said comparing means is operable to generate said comparison score during the progressive determination of said possible alignments.

24. An apparatus according to claim 21, wherein said dynamic programming means is operable to determine an optimum alignment between said input and said stored sequences of features and wherein said combining means is operable to provide said similarity measure by combining the comparison scores only for the optimum aligned pairs of features.

25. An apparatus according to claim 22, wherein said combining means is operable to provide said similarity measure by combining all the comparison scores for all the possible aligned pairs of features.

26. An apparatus according to any of claims 6, wherein each of the features in said input and stored sequences of features belong to said set of predetermined features.

27. An apparatus according to claim 26, wherein said similarity data comprises, for each feature in the set of features, the number of times the recognition processing means decodes the feature when it should have decoded a different feature, for each different feature, and the number of times the recognition processing means decodes anything when it should have decoded the different feature, for each different feature.

28. An apparatus according to claim 27, wherein said predetermined data further comprises, for each feature in the set of features, the probability of inserting the feature in a sequence of features.

29. An apparatus according to claim 26, wherein said predetermined data further comprises, for each feature in the set of features, the probability of deleting the feature from a sequence of features.

30. An apparatus according to claim 1, wherein said input and stored sequences of features represent time sequential signals.

31. An apparatus according to claim 1, wherein said input and stored sequences of features represent audio signals.

32. An apparatus according to claim 31, wherein said input and stored sequences of features represent speech.

33. An apparatus according to claim 32, wherein each of said features represents a sub-word unit of speech.

34. An apparatus according to claim 33, wherein each of said features represents a phoneme.

35. An apparatus according to claim 1, wherein said input sequence of features comprises a plurality of sub-word units generated from a typed input and wherein said similarity data comprises mis-typing probabilities and/or mis-spelling probabilities.

36. An apparatus according to claim 1, wherein said stored sequence of features comprises a sequence of sub-word units generated from a spoken input and wherein said similarity data comprises mis-recognition probabilities.

37. An apparatus according to claim 1, wherein said comparing means is operable to compare said input sequence of features with a plurality of stored sequences of features using said similarity data and said confidence data to provide a respective measure of the similarity between the input sequence of features and said plurality of stored sequences of features.

38. An apparatus according to claim 37, further comprising means for comparing said plurality of similarity measures output by said comparing means and means for outputting a signal indicative of the stored sequence of features which is most similar to said input sequence of features.

39. An apparatus according to claim 37, wherein said comparing means comprises normalising means for normalising each of said similarity measures.

40. An apparatus according to claim 39, wherein said normalising means is operable to normalise each similarity measure by dividing each similarity measure by a respective normalisation score which varies in dependence upon the length of the corresponding stored sequence of features.

41. An apparatus according to claim 40, wherein the

respective normalisation scores vary in dependence upon the sequence of features in the corresponding stored sequence of features.

42. An apparatus according to claim 40, wherein said comparing means comprises:

first comparing means for comparing, for each aligned pair, the input sequence feature in the aligned pair with each of a plurality of features taken from a set of predetermined features using said similarity data and said confidence data to provide a corresponding plurality of intermediate comparison scores representative of the similarity between said first sequence feature and the respective features from the set;

second comparing means for comparing, for each aligned pair, the stored sequence feature in the aligned pair with each of said plurality of features from the set using said similarity data and said confidence data to provide a further corresponding plurality of intermediate comparison scores representative of the similarity between said stored sequence feature and the respective features from the set; and

means for calculating said comparison score for the aligned pair by combining said pluralities of intermediate comparison scores; and

wherein said respective normalisation scores vary with the corresponding intermediate comparison scores calculated by said second comparing means.

43. An apparatus according to claim 42, wherein said aligning means comprises dynamic programming means for aligning said input and stored sequences of features

using a dynamic programming technique and wherein said normalising means is operable to calculate the respective normalisation scores during the progressive calculation of said possible alignments by said dynamic programming means.

44. An apparatus according to claim 43, wherein said normalising means is operable to calculate, for each possible aligned pair of features:

$$\sum_{r=1}^{n} P(a_i|p_r)P(p_r)$$

where $P(a_i|p_r)$ represents the probability of confusing set feature p_r as stored sequence feature a_i and $P(p_r)$ represents the probability of set feature p_r occurring in a sequence of features.

45. An apparatus according to claim 44, wherein said normalising means is operable to calculate said respective normalisations by multiplying the normalisation terms calculated for the respective aligned pairs of features.

46. An apparatus for searching a database comprising a plurality of information entries to identify information to be retrieved therefrom, each of said plurality of information entries having an associated annotation comprising a sequence of features, the apparatus comprising:

a feature comparison apparatus according to claim 1 for comparing a query sequence of features obtained from an input query with the features of each annotation to provide a set of comparison results; and

means for identifying said information to be retrieved from said database using said comparison results.

47. An apparatus according to claim 46, wherein said feature comparison apparatus has a plurality of different comparison modes of operation and in that the apparatus further comprises:

means for determining if the sequence of features of a current annotation was generated from an audio signal or from text, and for outputting a determination result; and

means for selecting, for the current annotation, the mode of operation of said feature comparison apparatus in dependence upon said determination result.

48. A feature comparison method comprising the steps of:

receiving an input signal;

a recognition processing step of comparing said input signal with stored feature models to identify an input sequence of features in said input signal and confidence data representative of the confidence that the input sequence of features is representative of said input signal; and

comparing said input sequence of features with a stored sequence of features using predetermined similarity data which defines similarities between different features and using said confidence data, to provide a measure of the similarity between the input sequence of features and the stored sequence of features.

49. A method according to claim 48, wherein confidence data is stored for said stored sequence of features and

wherein said comparing step provides said similarity measure using, in addition, said stored confidence data.

50. A method according to claim 48, wherein said confidence data comprises confidence data associated with each feature in the sequence of features.

51. A method according to claim 48, wherein said recognition processing step outputs a list of alternatives for each feature in said input sequence of features and confidence data associated with each alternative.

52. A method according to claim 48, wherein said comparing step comprises the steps of:

aligning features of the input sequence of features with features of the stored sequence of features to form a number of aligned pairs of features;

comparing the features of each aligned pair of features using said predetermined similarity data and said confidence data, to generate a comparison score representative of the similarity between the aligned pair of features; and

combining the comparison scores for all the aligned pairs of features to provide said similarity measure.

53. A method according to claim 52, wherein said comparing step comprises:

a first comparing step of comparing, for each aligned pair, the input sequence feature in the aligned pair with each of a plurality of features taken from a set of predetermined features using said similarity data and said confidence data to provide a corresponding

plurality of intermediate comparison scores representative of the similarity between said first sequence feature and the respective features from the set;

a second comparing step of comparing, for each aligned pair, the stored sequence feature in the aligned pair with each of said plurality of features from the set using said similarity data and said confidence data to provide a further corresponding plurality of intermediate comparison scores representative of the similarity between said stored sequence feature and the respective features from the set; and

a step of calculating said comparison score for the aligned pair by combining said pluralities of intermediate comparison scores.

54. A method according to claim 53, wherein said first and second comparing steps compare the input sequence feature and the stored sequence feature respectively with each of the features in said set of predetermined features.

55. A method according to claim 53, wherein said comparing step generates a comparison score for an aligned pair of features which represents a probability of confusing the stored sequence feature of the aligned pair as the input sequence feature of the aligned pair.

56. A method according to claim 55, wherein said first and second comparing steps provide intermediate comparison scores which are indicative of a probability of confusing the corresponding feature taken from the set of predetermined features as the feature in the aligned

pair.

57. A method according to claim 56, wherein said calculating step (i) multiplies the intermediate scores obtained when comparing the input and stored sequence features in the aligned pair with the same feature from the set to provide a plurality of multiplied intermediate comparison scores; and (ii) adds the resulting multiplied intermediate scores, to calculate said comparison score for the aligned pair.

58. A method according to claim 57, wherein each of said features in said set of predetermined features has a predetermined probability of occurring within a sequence of features and wherein said calculating step weighs each of said multiplied intermediate comparison scores with the respective probability of occurrence for the feature from the set used to generate the multiplied intermediate comparison scores.

59. A method according to claim 58, wherein said calculating step calculates:

$$\sum_{r=1}^{n} P(q_j|p_r)P(a_i|p_r)P(p_r)$$

where q_j and a_i are an aligned pair of input and stored sequence features respectively; $P(q_j|p_r)$ is the probability of confusing set feature p_r as input sequence feature q_j; $P(a_i|p_r)$ is the probability of confusing set feature p_r as stored sequence feature a_i; and $P(p_r)$ represents the probability of set feature p_r occurring in a sequence of features.

60. A method according to claim 59, wherein the confusion probabilities for the input and stored sequence features are determined in advance and depend upon the recognition system that was used to generate the respective input and stored sequences.

61. A method according to claim 59, wherein said calculating step calculates $P(q_j|p_r)$ using said similarity data and said confidence data.

62. A method according to claim 61, wherein said calculating step takes a weighted combination of said similarity data and said confidence data to determined $P(q_j|p_r)$.

63. A method according to claim 62, wherein said similarity data is obtained from a training session in which a large amount of input signals for which the feature content is known are processed by said recognition processing step and wherein said calculating step weighs said confidence data for a current feature in dependence upon the amount of training data available for the current feature in said training session.

64. A method according to claim 63, wherein said calculating step calculates:

$$P(q_j|p_r) = \frac{b_c c_{jr} + b_e e_{qj}^r + \beta}{b_c n_r + b_e + N_p \beta}$$

where c_{jr} and n_r are counts generated during the training session for the number of times the recognition processing step decoded feature q_j when it should have decoded feature p_r and the number of times the

recognition processing step decoded anything when it should have decoded feature p_r, respectively; e_{qj}^r is the confidence data associated with the input sequence feature of the aligned pair which is associated with the set feature P_r; β represents a lower limit of the confidence probabilities; N_p is the total number of features in the set; and b_c and b_e are scaling factors which are applied to the similarity data and the confidence data respectively.

65. A method according to claim 57, wherein said intermediate scores represent log probabilities and wherein said calculating step performs said multiplication by adding the respective intermediate scores and performs said addition of said multiplied scores by performing a log addition calculation.

66. A method according to claim 65, wherein said combining step adds the comparison scores for all the aligned pairs to determine said similarity measure.

67. A method according to claim 52, wherein said aligning step identifies feature deletions and insertions in said input and stored sequences of features and wherein said comparing step generates said comparison score for an aligned pair of features in dependence upon feature deletions and insertions identified by said aligning step which occur in the vicinity of the features in the aligned pair.

68. A method according to claim 52, wherein said aligning step comprises a dynamic programming step for aligning said input and stored sequences of features

using a dynamic programming technique.

69. A method according to claim 68, wherein said dynamic programming step progressively determines a plurality of possible alignments between said input and stored sequences of features and wherein said comparing step determines a comparison score for each of the possible aligned pairs of features determined by said dynamic programming step.

70. A method according to claim 69, wherein said comparing step generates said comparison score during the progressive determination of said possible alignments.

71. A method according to claim 68, wherein said dynamic programming step determines an optimum alignment between said input and said stored sequences of features and wherein said combining step provides said similarity measure by combining the comparison scores only for the optimum aligned pairs of features.

72. A method according to claim 69, wherein said combining step provides said similarity measure by combining all the comparison scores for all the possible aligned pairs of features.

73. A method according to claim 53, wherein each of the features in said input and stored sequences of features belong to said set of predetermined features.

74. A method according to claim 73, wherein said similarity data comprises, for each feature in the set of features, the number of times the recognition processing

step decodes the feature when it should have decoded a different feature, for each different feature, and the number of times the recognition processing step decodes anything when it should have decoded the different feature, for each different feature.

75. A method according to claim 74, wherein said predetermined data further comprises, for each feature in the set of features, the probability of inserting the feature in a sequence of features.

76. A method according to claim 74, wherein said predetermined data further comprises, for each feature in the set of features, the probability of deleting the feature from a sequence of features.

77. A method according to claim 48, wherein said input and stored sequences of features represent time sequential signals.

78. A method according to claim 48, wherein said input and stored sequences of features represent audio signals.

79. A method according to claim 78, wherein said input and stored sequences of features represent speech.

80. A method according to claim 79, wherein each of said features represents a sub-word unit of speech.

81. A method according to claim 80, wherein each of said features represents a phoneme.

82. A method according to claim 48, wherein said input

sequence of features comprises a plurality of sub-word units generated from a typed input and wherein said similarity data comprises mis-typing probabilities and/or mis-spelling probabilities.

83. A method according to claim 48, wherein said stored sequence of features comprises a sequence of sub-word units generated from a spoken input and wherein said similarity information comprises mis-recognition probabilities.

84. A method according to claim 48, wherein said comparing step compares said input sequence of features with a plurality of stored sequences of features using said similarity data and said confidence data to provide a respective measure of the similarity between the input sequence of features and said plurality of stored sequences of features.

85. A method according to claim 84, further comprising the step of comparing said plurality of similarity measures output by said comparing step and the step of outputting a signal indicative of the stored sequence of features which is most similar to said input sequence of features.

86. A method according to claim 84, wherein said comparing step comprises a normalising step for normalising each of said similarity measures.

87. A method according to claim 86, wherein said normalising step normalises each similarity measure by dividing each similarity measure by a respective

normalisation score which varies in dependence upon the length of the corresponding stored sequence of features.

88. A method according to claim 87, wherein the respective normalisation scores vary in dependence upon the sequence of features in the corresponding stored sequence of features.

89. A method according to claim 87, wherein said comparing step comprises:

a first comparing step of comparing, for each aligned pair, the input sequence feature in the aligned pair with each of a plurality of features taken from a set of predetermined features using said similarity data and said confidence data to provide a corresponding plurality of intermediate comparison scores representative of the similarity between said first sequence feature and the respective features from the set;

a second comparing step of comparing, for each aligned pair, the stored sequence feature in the aligned pair with each of said plurality of features from the set using said similarity data and said confidence data to provide a further corresponding plurality of intermediate comparison scores representative of the similarity between said stored sequence feature and the respective features from the set; and

a step of calculating said comparison score for the aligned pair by combining said pluralities of intermediate comparison scores; and

wherein said respective normalisation scores vary with the corresponding intermediate comparison scores calculated by said second comparing step.

90. A method according to claim 86, wherein said aligning step comprises a dynamic programming step for aligning said input and stored sequences of features using a dynamic programming technique and wherein said normalising step calculates the respective normalisation scores during the progressive calculation of said possible alignments by said dynamic programming step.

91. A method according to claim 90, wherein said normalising step calculates, for each possible aligned pair of features:

$$\sum_{r=1}^{n} P(a_i|p_r)P(p_r)$$

where $P(a_i|p_r)$ represents the probability of confusing set feature p_r as stored sequence feature a_i and $P(p_r)$ represents the probability of set feature p_r occurring in a sequence of features.

92. A method according to claim 91, wherein said normalising step calculates said respective normalisations by multiplying the normalisation terms calculated for the respective aligned pairs of features.

93. A method of searching a database comprising a plurality of information entries to identify information to be retrieved therefrom, each of said plurality of information entries having an associated annotation comprising a sequence of features, the method comprising:

a feature comparison method according to claim 48 for comparing a query sequence of features obtained from an input query with the features of each annotation to provide a set of comparison results; and

a step of identifying said information to be retrieved from said database using said comparison results.

94. A method according to claim 93, wherein said feature comparison method has a plurality of different comparison modes of operation and in that the method further comprises the steps of:

determining if the sequence of features of a current annotation was generated from an audio signal or from text, and outputting a determination result; and

selecting, for the current annotation, the mode of operation of said feature comparison method in dependence upon said determination result.

95. A method according to claim 93, wherein one or more of said information entries is the associated annotation.

96. A method according to claim 48, wherein the method steps are performed in the order in which they are claimed.

~~97~~. A storage medium storing processor implementable instructions for controlling a processor to implement a feature comparison method, the process steps comprising steps for:

receiving an input signal;

comparing the input signal with stored feature models to identify an input sequence of features in said input signal and confidence data representative of the confidence that the input sequence of features is representative of the input signal; and

comparing the input sequence of features with a

stored sequence of features using predetermined similarity data which defines similarities between different features and using said confidence data, to provide a measure of the similarity between the input sequence of features and the stored sequence of features.

98. A storage medium storing processor implementable instructions for controlling a processor to implement a method of searching a database comprising a plurality of information entries to identify information to be retrieved therefrom, each of the plurality of information entries having an associated annotation comprising a sequence of features, the process steps comprising:

the process steps stored on the medium according to claim 97 for comparing a query sequence of features obtained from an input query with the features of each annotation to provide a set of comparison results; and

a step of identifying said information to be retrieved from said database using said comparison results.

~~99~~. Processor implementable instructions for controlling a processor to implement a feature comparison method, the process steps comprising steps for:

receiving an input signal;

comparing the input signal with stored feature models to identify an input sequence of features in said input signal and confidence data representative of the confidence that the input sequence of features is representative of the input signal; and

comparing the input sequence of features with a stored sequence of features using predetermined similarity data which defines similarities between

different features and using said confidence data, to provide a measure of the similarity between the input sequence of features and the stored sequence of features.

100. Processor implementable instructions for controlling a processor to implement a method of searching a database comprising a plurality of information entries to identify information to be retrieved therefrom, each of the plurality of information entries having a associated annotation comprising a sequence of features, the process steps comprising:

the process steps of claim 99 for comparing a query sequence of features obtained from an input query with the features of each annotation to provide a set of comparison results; and

a step of identifying said information to be retrieved from said database using said comparison results.